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OF THE

AMERICAN PHYSICAL SOCIETY

PROGRAMME OF THE

HOUSTON MEETING

AT

HOUSTON, TEXAS

NOVEMBER 30 AND DECEMBER 1, 1951

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NOVEMBER 30, 1951 Vol. 26, No. 7

BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

1951 THANKSGIVING MEETING AT HOUSTON, TEXAS, NOVEMBER 30 AND DECEMBER 1, 1951

THE **309th meeting of the American Physical Society** will be held at Houston, Texas, in the buildings of the Rice Institute, on Friday and Saturday, November thirtieth and December first, 1951. The transposition of the Chicago meeting to October has allowed us to enjoy, for the second time in four years, the opportunity of holding the Thanksgiving meeting in Houston: the description "Thanksgiving meeting" is not in error, for Thanksgiving in Texas is celebrated on the last Thursday of November. The Local Committee (C. W. Heaps, *Chairman*) expects "Beautiful, clear, and balmy weather." The subzero weather of the 1950 Thanksgiving meeting is at any rate not to be expected: if it occurs, it will set a precedent in the history of Houston.

Hotel. The headquarters hotel is the Rice, and some rooms will also be available at the Shamrock: write immediately for your reservation (naming the Society) if you have not already done so. To go from the Rice Institute, take bus South Main 7400 or South Main 9200 (they pass the hotel); allow twenty minutes.

The **registration desk** will be located in the cloister of Fondren Library, new since our latest visit to Houston. Members and guests are asked to register, and frequently to consult the adjacent bulletin board for notice of messages.

The **scientific sessions** will be held in the Physics Laboratory and the Chemistry Laboratory of the Rice Institute. Invited papers on a variety of topics will be given by S. K. Allison, C. D. Anderson, T. W. Bonner, E. Feenberg, M. F. Kaplon, K. G. McKay, D. E. Muller, J. Rud Nielsen, R. T. Nieset, J. R. Pellam, H. C. Pollock, Henry Sommers, C. F. Squire, and M. S. Vallarta. Those on cryogenics are scheduled for Saturday morning, those on cosmic-ray phenomena for Friday afternoon, and those in nuclear physics mostly on Friday morning. Fifty-one contributed papers are distributed among five sessions on Friday afternoon and on Saturday.

The **banquet of the Society** will be held on Friday evening at seven o'clock in the Rice Institute Commons. W. V. Houston and M. S. Vallarta will be the after-dinner speakers. Tickets at **$2.50** will be sold at the registration desk. They should be purchased rather early on Friday, as presumably there will be a critical hour after which additional places cannot be guaranteed. If at all possible, please notify the Local Committee in advance of your intention to attend by using the form on the inside back cover page of this Bulletin.

On Saturday afternoon, from 4:30, the Rice Institute will offer **a tea** in Cohen House to members of the Society and to guests.

The **Council of the American Physical Society** will meet on Saturday afternoon at 2:30 o'clock in Room 231 of Fondren Library, unless contrary notice is sent to its members.

Post-deadline ten-minute papers, pertaining to very recent achievements of very special importance, will be considered for admission to a supplementary programme if the abstracts are received at the office of the Society not later than Friday, November 23. The abstracts of such papers as are accepted will not be printed; the titles will be announced on a blackboard near the registration desk, and the papers will be given under the usual ten-minute rule at the end of Session F.

Prospective meetings of the Society are scheduled for Berkeley, California, December 27–29, 1951; New York City, January 31, February 1–2, 1952; Columbus, Ohio, March 20–22; Washington, D. C., May 1–3; Denver, Colorado, June 30 to July 3. **Deadline for the New York meeting will be December seventh.**

General Rules for Presentation of Papers

The time allowed for the oral presentation of a ten-minute paper is ten minutes at most. The time allowed for the presentation of each invited paper is stated in the Bulletin.

When two or more contributed papers are submitted by the same members, all but one are placed on the "supplementary programme." (A paper by two or more members is credited, for this purpose, to the first person named in its by-line.) For each paper on this programme a session is indicated at the end of which it may be offered: but the Chairman is empowered to require that it be given in fewer than ten minutes, or to read it by title.

Titles and abstracts of the papers contributed to the 1951 Houston meeting are printed hereinafter, exactly as they will stand in a future issue of *The Physical Review*. Errata will be printed on an adjacent page of *The Physical Review* if received not later than Friday, December fourteenth, by Miss Ruth Bryans, 57 East 55 Street, New York 22, New York. Do not send in the abstract marked with corrections: write out the corrections in the form "instead of .... read ....". Do not add anything.

Speakers must retrieve their lantern slides before leaving the room in which the slides were shown. The Local Committee must not be burdened with the task of saving and returning them.

Karl K. Darrow, *Secretary*
American Physical Society
Columbia University
New York 27, New York

EPITOME OF THE HOUSTON MEETING

(Personal names are those of invited speakers.)

Friday Morning

A. Bonner, Allison, Feenberg, Pollock. Physics Amphitheatre.

Friday Afternoon

B. Nielsen, Muller; optics and general physics. Chemistry Lecture Hall.
C. Squire, Sommers, Pellam, Nieset. Physics Amphitheatre.
D. Nuclear physics. Physics Laboratory 210.

Friday Evening

Banquet of the American Physical Society; Houston, Vallarta. Rice Institute Commons.

Saturday Morning

E. Cryogenics; geophysics; Hughes. Chemistry Lecture Hall.
F. Vallarta, Kaplon, Anderson. Physics Amphitheatre.

Saturday Afternoon

G. McKay; solid and liquid states. Physics Amphitheatre.
H. Nuclear physics; cosmic rays; theoretical physics. Physics Laboratory 210.

Saturday Afternoon at Half-Past Four

Tea offered by Rice Institute. Cohen House.

PROGRAMME

FRIDAY MORNING AT 10:00

Physics Amphitheatre

(G. B. PEGRAM presiding)

Greetings from the President of Rice Institute.

Response by the President of the American Physical Society.

Invited Papers in Nuclear Physics

A1. Research at Rice Institute Using 14-Mev Monoenergetic Neutrons. T. W. BONNER, *Rice Institute.* (40 min.)

A2. Experiments on Light Nuclei and on Atomic Beams. S. K. ALLISON, *University of Chicago.* (30 min.)

A3. Nuclear Shell Structure. E. FEENBERG, *Washington University.* (40 min.)

A4. High Energy Electron and X-Ray Beams from the 80-Mev Synchrotron. [H.] C. POLLOCK, *General Electric Company.* (20 min.)

FRIDAY AFTERNOON AT 2:15

Chemistry Lecture Hall

(C. W. HEAPS presiding).

Invited Papers

B1. Vibrational Spectra of Fluorinated Hydrocarbons. J. RUD NIELSEN, *University of Oklahoma.* (30 min.)

B2. Recent Results with the Curved-Crystal Gamma-Ray Spectrometer. D. E. MULLER, *California Institute of Technology.*

Optics and general physics

B3. The Emission Spectra of Nitrogen Bombarded by High Energy Protons. R. J. SHALEK AND T. W. BONNER, *Rice Institute,* AND L. M. BRANSCOMB, *Harvard University.*—The spectra of nitrogen produced from its bombardment with protons from a Van de Graaff accelerator have been photographed in the region 2500–5000A with a quartz spectrograph. The prominent members of the second positive system of nitrogen and also the (0,0) band of the first negative system of singly ionized nitrogen appear. Spectra have been obtained when protons passed through air at a pressure of 15 cm of mercury; also at lower pressures of 4.0, 1.7, and 0.8 cm of mercury.

B4. Cathodoluminescence of Commercial Oxide Coated Cathodes. ARTHUR G. ROUSE, *St. Louis University,* AND JOHN B. DRAHMANN, *Seattle University.*—Flat cathodes were bombarded with an unfocused electron beam and the luminescence was studied spectrographically and with a photomultiplier. The temperature of the cathode was varied from $-140°$C to $+50°$C. The photomultiplier showed a maximum at $-125°$C in an $L-T$ curve. $L-V$ curves agreed with the law $L=kV^n$ with a possible increase in n at $-140°$C. The spectrograms showed various peaks and a visible phosphorescence was observed at low temperatures.

B5. A Point Focusing Monochromator for Low Angle X-Ray Diffraction. L. SHENFIL, W. E. DANIELSON, AND J. W. M. DUMOND, *California Institute of Technology.*—An anastigmatic point focus of monochromatic ($CuK\alpha_1$) radiation is achieved by means of two successive reflections from two cylindrically bent quartz crystals whose focal circles are mutually perpendicular. The sample is placed between the second crystal and the point focus, and the scattered beam is detected by means of a photographic film placed at the point focus at right angles to the undeviated beam. The diffraction patterns of a sample without large scale lattice structure appear as rings about the primary point focus and the interpretation of these is much simpler than in the case of a line-focused primary beam. Features as close as 6 minutes in angular measure from the primary beam can be resolved. The background fog without sample is roughly estimated as less than 1/5000 as intense as the primary beam at ten minute scattering angle. Diffraction rings out to the 20th order have been obtained with particles of Dow Latex 580 G lot 3584 (dry) and preliminary measurements of eleven rings from five different exposures yield a computed mean diameter 2692 ± 3A (value and precision subject to slight revisions with further work).

B6. Infrared and Raman Spectra and Calculated Thermodynamical Properties of CH_3-CH_2F and CH_3-CHF_2.* D. C. SMITH AND R. A. SAUNDERS, *Naval Research Laboratory,* AND J. RUD NIELSEN AND E. E. FERGUSON, *University of Oklahoma.*—The infrared absorption spectra of ethyl fluoride and 1,1-difluoroethane have been studied in the region 2–38μ for the compounds in the gaseous state and in the region 2–22μ for the liquids. Prisms of LiF, NaCl, KBr, and KRS-5 were employed. The Raman spectra of both compounds in the liquid state have been obtained with a three-prism glass

spectrograph of linear dispersion 15A/mm at 4358A. Depolarization ratios were determined for the stronger bands. The Raman spectrum of 1,1-difluoroethane was also obtained for the gaseous state. A complete assignment of fundamentals is proposed for each molecule and used for detailed interpretation of the spectra and for the calculation of thermodynamical functions over the temperature range 298–600°K and at the boiling point.

* Supported by the ONR and AEC.

B7. Infrared and Raman Spectra and Calculated Thermodynamical Properties of $CF_2=CHCl$.* J. RUD NIELSEN AND C. Y. LIANG, *University of Oklahoma*, AND D. C. SMITH, *Naval Research Laboratory*.—The infrared absorption spectra of gaseous and liquid 1,1-difluoro-2-chloroethylene have been obtained in the regions 2–22μ and 2–38μ, respectively, with the aid of LiF, NaCl, KBr, and KRS-5 prisms. The Raman spectrum of the compound in the liquid state has been photographed with a three-prism glass spectrograph of linear dispersion 15A/mm at 4358A. Relative intensities and depolarization ratios were determined for all but the weakest Raman bands. A complete assignment of fundamental vibration frequencies is given, the spectra are interpreted in detail, and thermodynamical functions are calculated for the temperature range 298–600°K.

* Supported by the AEC.

B8. Beer's Law Generalized and Applied to the Herzberg Continuum in Oxygen Gas. R. M. LANGER, *HICOG, Scientific Research Division*.—The large deviations from Beer's law in various continuous absorption spectra of O_n may be interpreted in terms of the weakening of selection rules when molecules react with light while undergoing collision. None of the published empirical formulas for the pressure dependence of the absorption coefficient are satisfactory even though some fit the data over a fivefold range of pressure. If the physical mechanism here favored is used to work out a generalization of Beer's law the result is a power series instead of the usual expression containing one term or irrational exponents. In the case of the Herzberg continuum, ($2000<\lambda<2400$A) which is of special significance in atmospheric physics, (N_2 molecules are comparable with O_2 in collision effectiveness) two terms are required and suffice to represent the data over a pressure range from 0.2 to 100 atmospheres. The formula is thus not only sounder than the others but is much wider in scope and range of applicability. For the case of room temperature Oxygen gas absorption at $\lambda=2150$A the decimal absorption coefficient α is $\alpha=7.1\times10^{-6}fp/p_0(1+1.25p/p_0)$ cm^{-1}, where f is the mole fraction of O_2 and p/p_0 is the total pressure in atmospheres. The constants change only slightly in the wavelength range $2000<\lambda<2400$A. These considerations are applied to rocket observations and atmospheric ozone theory.

B9. The Effect of Recent Mass Measurements on the Faraday. H. SOMMER, D. N. CRAIG, J. I. HOFFMAN, AND J. A. HIPPLE, *National Bureau of Standards*.—Recently we have reported in two parallel communications the measurement of the faraday by an electrochemical method using sodium oxalate and a physical method using the omegatron. These independent results agreed beautifully on the basis of the atomic and isotopic weights recommended at that time; we would like to point out that this agreement no longer obtains when one uses the mass spectroscopic values that have been reported since the publication of our earlier communications. The new value for the mass of H^1 raises the omegatron result by 18 ppm and the new value for Na^{23} lowers the sodium oxalate result by a greater amount. This resultant disagreement of approximately one part in 10,000 far exceeds the estimated probable errors of the two experiments.

B10. The Application of the Laplace Transformation and a Mechanical Harmonic Synthesizer in the Analysis of Electric Circuits. HERBERT D. SCHWETMAN, *Baylor University*, AND S. LEROY BROWN, *University of Texas*.—The purpose of this research was to demonstrate the applicability of a mechanical harmonic synthesizer to the solution of the operational equation related to the analysis of electric circuits. Specifically, the machine has been used to determine the roots of the polynomial in s (the derivative operator) found in the denominator of the equation $i_k=E_k(s)/D(s)$. In order to achieve this purpose, the mesh currents of several electric circuits, in which the numerical values of the circuit elements were known, were computed by use of the laplace transformation method in conjunction with the mechanical harmonic synthesizer. In designing a circuit to demonstrate a specified method, it was observed that the character of the roots of the polynomials could be predicted by use of the facts which follow: 1. For every mesh that consists of R–C elements or R–L elements there is one real root. 2. For every mesh that consists of R–L–C elements there are: a. At least one real root when $R/2>(L/C)^{\frac{1}{2}}$; b. Two real roots when $R/2=(L/C)^{\frac{1}{2}}$; c. Two conjugate complex roots when $R/2<(L/C)^{\frac{1}{2}}$ where R, L, and C are the effective values of the resistance, inductance, and capacitance of the elements in the mesh.

B11. Thermal Coefficients Applying to Deflection of Springs. RALPH W. MANN, *Humble Oil & Refining Company*.—For isoelastic materials (iron-nickel alloys) a critical examination shows that other constants in addition to the thermoelastic coefficient of Young's modulus contribute to the changes of flexural deflection with temperature under constant load. Timoshenko[1] has developed a formula $\delta=(PL^3/bh^3E)[(1-\mu^2)/(1-k\mu^2)]$ where δ = deflection, P = load, L = length, b = breadth, h = thickness, E = Young's modulus, μ = Poisson's ratio, and k is a factor involving the breadth, thickness, and curvature of the spring. Changing to dimensional form, differentiating with respect to temperature T, and simplifying, we obtain

$$\frac{1}{\delta}\frac{d\delta}{dT}=-\frac{1}{E}\frac{dE}{dT}-\frac{1}{L}\frac{dL}{dT}-\frac{2(1-k)\mu^2}{1-\mu^2}\frac{1}{\mu}\frac{d\mu}{dT}.$$

These terms, in order and considered with positive signs, are the deflection coefficient of the spring, the thermal coefficient of Young's modulus, the coefficient of thermal expansion, and a factor times the thermal coefficient of Poisson's ratio. A similar formula applies to torsional deflection.

[1] G. Timoshenko, Mech. Eng. **45**, 259 (1923).

FRIDAY AFTERNOON AT 2:15

Physics Amphitheatre

(W. V. HOUSTON presiding)

Invited Papers in Cryogenics and Biophysics

C1. Results from Low Temperature Studies at Rice Institute. C. F. SQUIRE, *Rice Institute.* (30 min.)

C2. Experimental Investigations of Liquid Mixtures of Helium 3 and Helium 4. HENRY SOMMERS, *Los Alamos Scientific Laboratory.* (30 min.)

C3. Experiments on Second Sound in Liquid Helium II. J. R. PELLAM, *National Bureau of Standards.* (30 min.)

C4. Recent Work in the Biophysics Laboratory at Tulane University. ROBERT NIESET, *Tulane University.*

FRIDAY AFTERNOON AT 2:15

Physics Laboratory 210

(T. W. BONNER presiding)

Nuclear physics

D1. Tracer Studies on Alligator Weed Using 2,4-D-C^{14}. KARLEM RIESS, T. T. EARLE, AND JOHN HIDALGO, *Tulane University.*—A study of 2,4-D (2,4-dichlorophenoxyacetic acid) labeled with carbon-14 in alligator weed (*Alternanthera philoxeroides* (Mart). Griseb.) was undertaken to determine the distribution, the rate and mode of transport of this herbicide with the plant. It was found that the distribution was somewhat uneven, more going up than down, at a rate of approximately 4.3 centimeters per hour. The mode of travel was through the vascular bundles and the epidermal tissue of the plant. Manual maceration and extraction of 2,4-D with ethyl alcohol proved the best method of sample preparation. The addition of a wetting agent, Tween 20, did not increase the rate of travel or distance traveled, but did affect the quantity of 2,4-D absorbed by the plant. This work was part of a project to control aquatic pests in the navigable inland waterways of the South.

D2. Preparation of Thin Zirconium Tritium Targets.* J. P. CONNER AND J. R. SMITH, *Rice Institute.*—In the preparation of very thin tritium by evaporation of zirconium metal and absorption of tritium into it as described previously,[1] considerable difficulty was encountered when targets with zirconium films about 10 micrograms/cm^2 were desired. Improvements in technique necessary for making these very thin targets will be discussed. Targets have been prepared on tungsten, aluminum and beryllium blanks with tritium-zirconium atomic ratios as high as 1–1½.

* This work assisted by the AEC program.

[1] A. B. Lillie and J. P. Conner, Rev. Sci. Instr. **22**, 210–211 (1951).

D3. An 800-kc Cockroft-Walton Generator. WM. A. ROBBA,* *A & M College of Texas.* (Introduced by J. G. Potter.)—The generator was constructed to provide a stable source of 100 μamp at 120 kv and to explore the feasibility of constructing similar units operable at much higher voltages, realizing the gains in efficiency, regulation, compactness and economy inherent in rf supplies. A small driver feeds a two stage push-pull power amplifier, which in turn is coupled to a 13-stage multiplier stack through a step-up transformer. The stack condensers are 0.035 μf at 10,000 v, and the rectifiers are 1 B 3 tubes with the filaments heated by rf. 180 watts are required by the power amplifier for the indicated output. Tube failures limited the voltages obtained. At higher frequencies the large stray capacitance of the rectifier condenser stack prevented an effective match for the step-up transformer. It is concluded that greatly increased voltages will be obtained when rectifier tubes and condensers of better design, now available, are employed.

* Now student at Oak Ridge School of Reactor Technology.

D4. Differential Cross Section of $H^3(d,p)T^3$ at Low Energy.* CHARLES F. COOK AND J. RICHARD SMITH, *Rice Institute.*—Measurements of the 90° differential cross section of the reaction $H^3(d,p)T^3$ are being investigated using a Cockroft Walton Particle Accelerator, over the range of 40–180 kev deuteron energy. Protons are counted with a proportional counter. Thin deuterium targets are prepared by evaporation of heavy paraffin on polished target blanks in high vacuum. Target thicknesses are accurately determined by evaporating heavier quantities of paraffin on blanks and weighing to approximately 1 percent accuracy, then extrapolating to the range of interest. Targets ranged from 5–10 micrograms per cm^2 which corresponds to a few kev thickness at 100-kev deuteron energy.

* This work was assisted by the AEC program.

D5. The Disintegration of Lithium by Deuteron Bombardment. L. M. BAGGETT* AND S. J. BAME, JR.,* *Rice Institute.*—Thin target excitation curves for $Li^7(d,n)$, $Li^6(d,n)$, and $Li^7(d,p)$ reactions are presented. The neutron data were taken at 90 degrees to the deuteron beam using a BF_3 filled proportional counter in the long geometry. Resonances were observed in the $Li^6(d,n)$ reaction at 0.41 and at 2.12 Mev; in the $Li^7(d,n)$ reaction at 0.68, 0.98, and 2.1 Mev; and in the $Li^7(d,p)$ reaction at 0.75, 1.00, and 1.4 Mev. These resonances correspond to excited states in Be^8 at 22.58 and 23.68 Mev and in Be^9 at 17.22, 17.45, 17.80, and 18.3 Mev. The cross sections of the resonances observed in the $Li^6(d,)$ reaction were 9 and 41 millibarns/steradian; those for the $Li^7(d,n)$ reaction were 39, 43, and 58 millibarns/steradian; and those for the $Li^7(d,p)$ reaction were 0.230, 0.235, and 0.255 barn.

* Now at the Los Alamos Scientific Laboratory.

D6. $p-\gamma$ Angular Correlation in the Reaction $Li^6(d,p)Li^7$* at Low Energy. W. H. BURKE AND J. R. RISSER, *Rice Institute.*—At low bombarding energies (375 kev) the experimental cross section of the $Li^6(d,p)Li^7$ reaction when corrected for

barrier penetration gives indication of a broad resonance level in Be^8.[1] In the hope of throwing light on the character of this Be^8 state, the angular correlation of protons and the 480-kev gammas from Li^{7*} was measured using coincidence equipment with resolving time of 0.08 μsec and with energy selection for the gamma-radiation. $p-\gamma$ coincidences were found to be independent of the angle between the direction of emission of proton and gamma-ray to within 10 percent, the present statistical accuracy of the measurements. 500-kev deuterons were used, since at this energy the yield is almost entirely due to the Be^8 level. This work was assisted by the joint program of the ONR and AEC.

[1] W. Whaling and T. W. Bonner, Phys. Rev. **79**, 258 (1950).

D7. Angular Correlation Studies of $(d; p, \gamma)$ Processes of the Target Nuclei Li^6, B^{10}, and O^{16}. G. C. PHILLIPS,* N. P. HEYDENBURG, D. B. COWIE. *Carnegie Institution of Washington.*—The angular correlation of $(d; p, \gamma)$ reactions have been investigated for the target nuclei Li^6, B^{10}, and O^{16}. Medium thin targets were bombarded by monoenergetic deuterons accelerated by the pressure electrostatic generator. The energy of the deuterons was 1.0 Mev for the Li^6 target, 1.81 Mev for the B^{10} target, and 1.70 and 2.04 Mev for the oxygen target. The enriched Li^6 and B^{10} isotopes were supplied by the Isotopes Division, AEC, Oak Ridge. The angular correlations were obtained by observing proton-gamma-ray coincidences with apparatus having a time resolution of 10^{-8} sec. The angular correlation functions observed were all isotropic within the statistical errors. The absence of correlations will be discussed. For Li^6 and B^{10} isotropy is perhaps explicable, but the isotropy for O^{16} was not expected.

* Fellow of the Carnegie Institution of Washington, on leave from the Rice Institute, Houston, Texas. [redacted]

D8. Evidence for Stripping in the $B^{10}(d,n)C^{11}$ Reaction at Low Deuteron Energies. J. R. RISSER AND W. H. BURKE, *Rice Institute.*—The theory of stripping[1] predicts preferential forward emission of the uncaptured nucleon when a deuteron reaction proceeds by stripping rather than by formation of a compound nucleus. While apparently the effect of potential barrier has not been evaluated in the theory, it would seem reasonable that the forward emission might persist to low bombarding energies. We have observed pronounced forward emission with peaks in the region 35°–40° for the neutrons from $B^{10}(d,n)C^{11}$ reaction for bombarding energies from 0.8 to 1.6 Mev, the peaks occurring at approximately the same angle for all energies. In order to explain this effect in compound nucleus formation, deuteron angular momenta with l of at least 2 would be required. The fact that the effect persists to deuteron energy as low as about 1 Mev is interpreted as evidence that the reaction proceeds at least in part by stripping. This work was assisted by the joint program of the ONR and AEC.

[1] S. T. Butler, Proceedings of the Harwell Conference (1950).

D9. Inelastic Scattering of Protons from Light Nuclei. N. P. HEYDENBURG, G. C. PHILLIPS,* AND DEAN B. COWIE, *Carnegie Institution of Washington.*—An investigation was made of inelastic scattering of 7.4-Mev protons at 90° from the following thin foil targets: Be^9, C^{12}, C^{13} (47 percent) CaF_2, Ni, Al, and Na, and from the following gas targets: Normal BF_3, enriched $B^{10}F_3$ (96 percent), N_2, O_2, CH_4, and Ne. The following energy levels in Mev were observed: Be^9 2.57; B^{10} 2.34; B^{11} 2.06; C^{12} 4.20; N^{14} 2.35, 3.95; O^{16} none; F^{19} 1.53, 3.83; Ne 1.44, 4.36; Na^{23} 3.67; Al 1.02, 2.30, 2.89, 3.32, 4.48; and Ni 1.44. The scattered protons were observed using double coincidence proportional counters. Ranges and energies were determined with calibrated aluminum foils.

* Research Fellow, Carnegie Institution of Washington.

D10. A Study of the 1435-kev Resonance of Carbon Bombarded by Deuterons. K. FAMULARO, L. C. THOMPSON, AND T. W. BONNER, *Rice Institute.*—The yield of the $C^{12}(d,n)N^{13}$ reaction as a function of bombarding energy has been investigated in the region of $E_d = 1435$ kev. Previous experiments failed to detect a resonance for neutron production at this energy, although a narrow resonance was observed there for gamma and proton production in the competing reactions. An improved method of observation involving a larger solid angle of the detector and a greater efficiency of counting was used to search for a neutron resonance. A weak resonance with a width of about 6 kev was observed at the same energy (1435) as that shown by the competing reactions. An anomaly in the elastic scattering cross section for deuterons scattered by carbon has been observed in this same range of bombarding energy, through the use of a magnetic analyzer.

D11. Neutron Yields from the Nuclear Photoeffect. J. S. LEVINGER, *Louisiana State University,* AND H. A. BETHE, *Cornell University.*—The yields of neutrons produced in photonuclear reactions by 300-Mev bremstrahlung[1,2] *appear* to increase more rapidly with atomic number than the neutron yields predicted from theory.[3] We analyze the yields for elements from copper to uranium in terms of multiplicity of neutron production, approximating the neutron multiplicity n as proportional to the photon energy W: i.e., $n = W/E$. E, the average energy expended per neutron emitted, is calculated from the compound nucleus model. E is about equal to $\frac{2}{3}$ the neutron binding energy, thus decreasing with increasing Z. (We calculate how much E is increased above this value for low Z due to proton competition; it is presumably decreased for uranium by photofission.) The experimental yields give an integrated photonuclear cross section equal to 0.14 (NZ/A) Mev-barns. (The yield for uranium is 35 percent high.) This integrated cross section has the correct form as, but a somewhat higher absolute value than, the theoretical result[3] of 0.060 $(NZ/A)(1+0.8x)$, where x is the fraction of exchange force.

[1] D. W. Kerst and G. A. Price, Phys. Rev. **79**, 725 (1950).
[2] Terwilliger, Jones, and Jarmie, Phys. Rev. **82**, 820 (1951).
[3] J. S. Levinger and H. A. Bethe, Phys. Rev. **78**, 115 (1950).

D12. On the Radioactivity of Ag^{108}. MAX GOODRICH,* *Louisiana State University,* AND EDWARD C. CAMPBELL, *Oak Ridge National Laboratory.*—Most nuclear tables list no gamma-rays in the activity of 2.3-min Ag^{108} and give 2.8 Mev as the beta-ray end point. Recent measurements on this isotope made at Oak Ridge National Laboratory with a scintillation spectrometer have shown gamma-rays of 0.61 ±0.02 Mev, 0.42±0.02 Mev, and 0.19±0.02 Mev to be present in relative numbers ~4:1:1. The beta-ray end point was found to be 1.49±0.05 Mev with no higher energy beta-ray present to more than a few percent of the total. Coincidence experiments indicated that the gamma-rays are not in cascade with the beta-ray. An examination of the x-ray spectrum, made with a proportional counter, showed the energy of the x-rays to be lower than the K x-rays of Ag. Ag^{108} is then presumed to decay both by K-capture to excited levels of the Pd^{108} nucleus and by beta-decay to the ground state of Cd^{108}. The branching ratio is roughly $(N_\beta/N_K) = 2$.

* Research participant of the Oak Ridge Institute of Nuclear Studies.

D13. Delayed γ-Emission from Decay of C^{15}. EMMETT L. HUDSPETH AND WILLIAM B. ROSE, *University of Texas,** AND N. P. HEYDENBURG, *Carnegie Institution of Washington.*—Intense γ-radiation has been observed in the decay of C^{15}, which was produced by deuteron bombardment at 1.8 Mev of a $BaCO_3$ target in the C.I.W. statitron. The $BaCO_3$ was obtained from Oak Ridge and had a carbon isotopic ratio of 4.77 percent C^{14}. The decrease in intensity of the γ-radiation

showed the same 2.4-second half-life as the β-decay[1] of C^{15}. Coincidence absorption data show that the energy of the most prominent γ-radiation is approximately 5.5 Mev, corresponding to the first excited level of N^{15}. An attempt was made to perform $\beta-\gamma$ coincidence measurements with Geiger counters, but the high background counts from other radioactive elements and the relatively low concentration of C^{14} in our target made this impossible. We plan to do this under more favorable conditions with crystal counters. The β-emission of C^{15} and the excitation curve for its production have been studied in more detail.

* Assisted by the AEC.
[1] Hudspeth, Swann, and Heydenburg, Phys. Rev. **80**, 643 (1950).

D14. Neutrons from the Deuteron Bombardment of F^{19}. J. W. BUTLER, *Naval Research Laboratory*.—A survey has been made for neutron thresholds in the reaction $F^{19}(d,n)Ne^{20}$ using similar techniques to those previously described.[1] No thresholds have been observed between 0.5 and 2 Mev although an indication of a level at 11.5 Mev is reported[2] in Ne^{20}, which should give a threshold at about 0.8 Mev. A further search for thresholds is being made using a modified technique. The excitation function at 0° for the reaction has been made using a flat response detector. The function increased smoothly from 0.5 to 2 Mev and was similar in appearance to the curve obtained with the threshold counter.

[1] T. W. Bonner and J. W. Butler, Phys. Rev. **83**, 1091 (1951).
[2] James Terrell and G. C. Phillips, Phys. Rev. **83**, 703 (1951).

FRIDAY EVENING AT 7:00

Rice Institute Commons

(C. C. LAURITSEN presiding)

Banquet of the American Physical Society

After-dinner speakers: W. V. Houston and M. S. Vallarta

SATURDAY MORNING AT 10:00

Chemistry Lecture Hall

(C. F. SQUIRE presiding)

Cryogenics; Geophysics

E1. The Resistance Variation of MnSe at Low Temperatures. JOHN SCALES AND C. W HEAPS, *Rice Institute*.—MnSe has been found[1] to have an antiferromagnetic Curie temperature at about −110°C. Recent experiments indicate that this material may go through phase transitions as its temperature is lowered. Lindsay has detected[2] three phases between 0°C and −190°C, and two of these phases appear to be antiferromagnetic. We have measured the electrical resistance of various samples of MnSe and found that the temperature-resistance curves show anomalies. A hysteresis effect is observed which may be associated with a time lag of the phase changes. Three different slopes of the resistance curve during three different temperature ranges are interpreted as being due to the successive appearances of three different phases. A possible resistance change caused by the appearance of antiferromagnetism has not been detected. If it exists it is masked in this material by the phase changes.

[1] C. F. Squire, Phys. Rev. **56**, 922 (1939).
[2] Robert Lindsay, Phys. Rev. **84**, 569 (1951).

E2. Abiabatic Thermal Changes in Barium Titanate Ceramic and Strontium Titanate Ceramic at Low Temperatures. R. W. SCHMITT AND R. T. SWIM, *Rice Institute*.—The adiabatic thermal changes at 4°K in barium titanate ceramic show a heating effect whether the electric field is applied or removed. An interpretation of these results is that the polarization process is thermodynamically irreversible. The large temperature dependence of the dielectric constant at 4°K may be understood as a result of the thermodynamically irreversible polarization. Quantitative results are given as to the temperature rise as a function of electric field strength and as a function of temperature. The results of similar measurements on strontium titanate ceramic, whose dielectric constant has a different temperature dependence from that of $BaTiO_3$, are also discussed.

E3. Studies of Superconductivity with a Torsion Pendulum. ARTHUR L. LATHROP, *Rice Institute*.—The torsion pendulum consists of a tungsten wire fiber to which is attached a tin sphere. Damping and period measurements have been made on this system in different magnetic fields and at different temperatures. Measurements of this sort enable one to measure the different steady state and transient torques that operate on the system when the tin is in the normal and in the superconducting state.

E4. Temperature Dependence of Electrical Conductivity. W. V. HOUSTON, *Rice Institute*.—Recent measurements of the electrical conductivity of pure metals over a wide range of temperature have made possible an evaluation of the theories. General considerations indicate, that the resistance will be proportional to T at high temperatures and will approach proportionality to T^5 at very low temperatures. The behavior at intermediate temperatures depends more on details of the electron scattering process and varies from metal to metal. Two effects have been considered. In 1929 a parameter was introduced to describe the angular dependence of the scattering by an individual ion. Proper selection of this parameter and θ permits rather satisfactory description of the resistances of sodium and lithium as reported by MacDonald and Mendelssohn. The necessary value of θ, however, is not the one to be expected on the basis of the elastic constants. Consideration of the normal vibrations of a crystal shows that the division into longitudinal and transverse waves is valid only for long wavelengths. For short wavelengths most vibrations have longitudinal components. An approximate method of taking

them into account gives a good description of the observations with reasonable values of the characteristic temperatures.

E5. Experimental Laboratory Studies of Elastic Wave Propagation. W. L. ROEVER, *Shell Oil Company.*—A technique is described which is analogous to the method used in seismic exploration and which is applied to model acoustic systems set up in the laboratory. A spark is used to generate transient elastic waves and piezoelectric or other detectors are used to convert the resulting pressures or displacements to voltages. These are amplified and displayed as a function of time on a cathode-ray tube where they are photographed. A two-layer system consisting of a layer of water over a layer of concrete was studied. The experimental dispersion curves are compared with the theoretical curves for normal mode propagation as given by Press and Ewing[1] for a liquid layer over a semi-infinite solid. (Longitudinal and transverse wave velocities of solid larger than longitudinal velocity of liquid.) The constants were adjusted to fit measured values for concrete. The results are in good agreement and we believe are the first experimental results to be compared with the theory at frequencies less than the frequency of the Airy phase.

[1] F. Press and M. Ewing, Trans. Am. Geophysical Union, Vol. 29, No. 2, April, 1948.

E6. On the Propagation of Rayleigh Waves on the Surface of a Visco-Elastic Solid. C. W. HORTON, *University of Texas.*—Scholte[1] has shown that a wave can be propagated over the surface of a visco-elastic solid and that this wave reduces to the well-known Rayleigh wave when the viscosity of the solid approaches zero. The cubic equation which governs this wave has been solved for the case of a poisson solid ($\lambda=\mu$). The behavior can be characterized by a dimensionless parameter $\delta=\omega\eta/\mu$ where ω is the angular frequency, η is the coefficient of viscosity, and μ is the shear modulus. For the range of physical parameters of interest in seismology and seismic prospecting δ is less than 0.1 and the modification of the classical Rayleigh motion is very slight. The presence of internal friction changes the difference in phase angle between the vertical and horizontal displacements from $\pi/2$ to $\pi/2-0.1014\delta$ for small δ. The ratio between the vertical and horizontal maximum displacements remains equal to 1.468 independently of the value of δ. The wave motion has an attenuation factor of $2.908\delta/\lambda_0$ where λ_0 is the wavelength of the Rayleigh wave in the same medium in the absence of internal friction.

[1] J. G. Scholte, Physica **13**, 245 (1947).

E7. Wave Propagation Ducts in Geophysics. Lynn G. HOWELL, *Humble Oil and Refining Company.*—The occurrence of ducts in propagating both elastic and electromagnetic waves is pointed out along with their similarities. The dispersive propagation of longitudinal elastic waves was observed in a duct-layer over the Hawkinsville Salt Dome in the Gulf Coast region of Texas. Also, an example of the dispersion of Rayleigh waves produced by layering is given. In general, with Rayleigh waves the high frequency branch of the dispersion curve has not been observed in land areas; however, there is some evidence that this branch does exist in a particular Gulf Coast area. Atmospheric ducts for microwaves are found over the Gulf of Mexico with the summer season being the optimum period. During the winter season the meteorological conditions are more variable.

Invited Paper

E8. Elastic Constants of Rocks at High Pressures and Temperatures. D. S. HUGHES, *University of Texas.* (25 min.)

SATURDAY MORNING AT 10:00

Physics Amphitheatre

(C. C. LAURITSEN presiding)

Invited Papers on Cosmic-Ray Phenomena

F1. Recent Research in Cosmic Radiation and Radio Waves Emitted by the Sun. M. S. VALLARTA, *Universidad de México.* (25 min.)

F2. Multiple Meson Production at Extremely High Energies. M. F. KAPLON, *University of Rochester.* (30 min.)

F3. Report on *V*-particles. C. D. ANDERSON, *California Institute of Technology.* (40 min.)

Post-Deadline Papers, If Any

SATURDAY AFTERNOON AT 1:30

Physics Amphitheatre

(C. P. BONER presiding)

Invited Paper

G1. Crystal Counters. K. G. MCKAY, *Bell Telephone Laboratories.*

Solid and Liquid States

G2. Dipole Lattice in the Spherical Model.* MELVIN LAX, *Syracuse University.*—The statistical mechanical treatment of a lattice of classical dipoles, electric or magnetic, has been intractable because of the restriction of fixed length of the dipoles. The spherical model consists in replacing the above stringent restriction by the weaker restriction that the sum of

the squares of the dipole vectors have the correct value, thus permitting some, but not much, fluctuation from the correct situation. The spherical method has previously been applied by T. H. Berlin and J. S. Thomsen (ONR report, 1950) to the dipole lattice problem including the appropriate tensor coupling but only nearest-neighbor interactions. The present paper reports a generalization of the previous work to include interactions between all neighbors. The evaluation of the partition sum in the presence of long-range forces requires care because some of the eigenvalues depend on the shape of the specimen. A formula has been derived, however, for the susceptibility, in which the shape dependence of the specimen is explicitly shown to cancel. Qualitative agreement is found with the nearest-neighbor calculation: At sufficiently low temperatures, for purely dipole-dipole interactions, an antiferroelectric transition is observed for three-dimensional crystals, but not in one or two dimensions.

* This work has been supported in part by the ONR.

G3. Modification Functions in the Fourier Inversion of Diffraction Data. JÖRG WASER, *Rice Institute.*—The reduced intensity function $I(s)$ describing essentially the diffraction of particles or waves by scattering matter can be fourier inverted to yield a radial distribution function

$$D(r)/r = \text{const} \int_0^\infty I(s) \sin sr ds.$$

If $I(s)$ be modified by multiplication with a suitable function $M(s)$ the result of inversion of $I(s)M(s)$ is

$$D'(r)/r = \text{const} \int_{-\infty}^{\infty} T(u-r)D(u)/u du,$$

which represents the folding of the original $D(r)/r$ with the cosine transform $T(r)$ of $M(s)$

$$T(r) = \text{const} \int_0^\infty M(s) \cos sr ds.$$

Of special interest are functions $M_f(s)$ which are zero for $s \geq s_0$. It is found that the functions $T(r)$ related to such $M_f(s)$'s must be of the form

$$T(r) = \Sigma_n a_n J_{2n+\frac{1}{2}}(s_0 r)/(s_0 r)^{\frac{1}{2}},$$

where the J's are bessel functions. The properties of these functions will be discussed in relation to the shape of the peaks of $D(r)/r$, and illustrated by examples. An analogous theorem holds for the fourier and Patterson analyses of scattering information from crystals.

G4. Experimental Studies on Quartz Resonators. K. S. VAN DYKE AND W. F. PALMER, *Wesleyan University.**—Progress along two lines is reported. (1) The Q's of small rings cut from natural quartz have been pushed up into the millions. A Z-cut ring 1¾ inches in diameter vibrating in circumferential longitudinal compression at 160 Kc attains a Q of 3.2×10^8 in vacuum. Of particular interest are the several-fold progressive increase to this value during three months of baking at 125°C, the rapid absorption of atmospheric water vapor and the retention of the latter until baking is renewed. Q's of 2×10^6 hold for a 2.1 mc thickness-shear resonance of a thin BT-cut plate ($5.2\times5.2\times0.26$ cm). (2) Studies of the distribution of strain throughout square AT- and BT-cut thickness-shear resonators have been extended to include rectangular and circular plates, still using partial plating and electrical impedance measurements as the surveying tools. The decrease of amplitude from the center outward in the circular plates is not symmetrical to the plane of the shear but shows a preference for certain directions inclined to this plane. In the circular plate, particularly, very minor irregularities of boundary seem to have considerable effect on the distribution pattern.

* This work was supported by contract with the U. S. Signal Corps.

G5. The Antiferromagnetic Structure of Manganese Dioxide by Neutron Diffraction. R. A. ERICKSON,* *Oak Ridge National Laboratory.*—Neutron diffraction patterns from MnO_2 have been obtained at several temperatures between 20 and 300°K. The room temperature pattern consists of the superposition of coherent nuclear peaks on a background of characteristic paramagnetic diffuse scattering. At 20°K the magnetic scattering is almost completely coherent as indicated by the small magnetic diffuse scattering and the presence of several super-lattice magnetic reflections. The positions and intensities of these peaks are accounted for with an antiferromagnetic model having unit cell dimensions twice those of the chemical cell. In this model the magnetic moments are normal to the tetragonal axis in antiparallel rows along each of the crystal axes. The body centered and lattice corner moments thus form two antiferromagnetic sublattices. From the powder diffraction pattern alone it is not possible to assign unique alignment directions within the base plane to the moments of either sublattice. However, this model is entirely consistent with the single crystal susceptibility measurements of Bizette and Tsai[1] if the moments in one sublattice are normal to those in the second.

* Graduate Fellow of the Oak Ridge Institute of Nuclear Studies, now at the University of Tennessee.
[1] Bizette and Tsai, *Colloque sur les phénomènes cryomagnétiques* (Perrin-Langevin, 1948).

G6. Electrical Properties of Rutile Single Crystals.* L. F. CONNELL† AND R. L. SEALE, *University of Texas.*—Electrical properties of single crystals of reduced synthetic rutile have been studied with emphasis upon applicability as a semiconductor. The principal type of conduction has been verified and the density and mobility of carriers estimated. Other dc measurements included tests on point rectification, bulk resistivity, and barrier-layer potential for a number of samples carried in steps from a normal, fully-oxidized condition to a highly reduced state. Consistent rectification ratios did not exceed 10:1. Bulk resistivity in any given degree of reduction appeared ohmic; barrier-layer effects agreed well with predictions of the Mott-Schottky theory for extrinsic semiconductors. Ac measurements included tests on capacitance and loss-factor for samples over the range of reduction at frequencies up to 50 kc using a General Radio 716 capacitance bridge in a parallel-resistance method. The total capacitance showed anomalous dispersion of the apparent dielectric constant over the frequency range. A satisfactory equivalent circuit has been found, as tested by plotting the series resistance and reactance in the complex plane. The high capacitances were shown to be due to the high barrier potential, with the controllable bulk resistance of the rutile shunting its low bulk capacitance.

* The work described was done at Defense Research Laboratory under the ponsorship of the Bureau of Ordnance, Navy Department.
† Now at North Texas State College, Denton, Texas.

G7. The Time Rate of Transformation of α-Monoclinic Selenium into Hexagonal as a Function of the Temperature. JOHN MURPHY AND ARTHUR E. LOCKENVITZ, *University of Texas.*—α-Monoclinic selenium prepared by precipitation from a solution of selenium in carbon bisulfide was used as the dielectric between the plates of an aluminum plate condenser. Above about 90°C α-monoclinic selenium transforms into hexagonal via an intermediate form, probably β-monoclinic. The transformation at a fixed temperature can be followed with time by measuring the capacity of the condenser containing the selenium. The data from capacity measurements fit the laws $dN_1/dt = -\lambda_1 N_1$ and $dN_2/dt = -\lambda_2 N_2$ where N_1 and N_2 are the number of molecules of the α- and β-forms, respectively, and λ_1 and λ_2 are different functions of the temperature. It is assumed that form α transforms to form β which in turn transforms to the stable hexagonal form. λ_1 and λ_2 appear

to be some exponentially increasing functions of the temperature.

G8. The Time Rate of Transformation of Amorphous Selenium into Another Form as a Function of Temperature. ARTHUR E. LOCKENVITZ AND KENNETH H. RIBE, *University of Texas.*—Amorphous selenium precipitated from a dilute HCl solution of selenious acid was used as the dielectric between an aluminum plate condenser whose capacity was measured at 3 megacycles with a General Radio 821A twin T bridge. Above 25°C amorphous selenium transforms to another form, probably α-monoclinic, with a resultant change in dielectric constant and capacity of the condenser. The time rate of change of capacity at constant temperature in the region between 20°C and 50°C increased with temperature. $\text{Log}(1-\Delta c/\Delta c_f)$ plotted against time gives essentially a straight line within the limits of experimental error, the slope of the straight lines being greater at higher temperatures. Δc and Δc_f are the change in capacity at time t and infinity, respectively. This suggests the law of transformation to be $\Delta c = \Delta c_f \exp(-\lambda t)$ where λ is a function of the temperature. It is hoped that the form of $\lambda = F(T)$ can be determined.

G9. Investigations on the Debye-Frenkel Theory of Ultrasonic Absorption. P. A. HUDSON* AND M. EISNER, *A & M College of Texas.*—The Debye-Frenkel theory postulates the existence of molecular rearrangements to account for the anomolies observed in the absorption of ultrasonic waves in liquids. An attempt was made to study the effect of these rearrangements by comparing the absorption in isomeric liquids and by inducing rearrangements by compression. Allyl alcohol and acetone were selected for the isomeric study and ethyl ether was used in studying the pressure dependence. The absorption coefficients, measured at 3.5 mc by a pulse echo technique, were 0.0087 cm^{-1} for allyl alcohol and 0.0053 cm^{-1} for acetone. Comparing these values with those predicted by the classical Stokes-Kirchoff theory reveals that the more highly associated liquid, allyl alcohol, shows an absorption closer to the classical value than does acetone. This is in qualitative agreement with the prediction of the Debye-Frenkel theory. The experiments on ethyl ether failed to reveal a significant pressure dependence for the absorption for pressures up to 2 atmospheres.

* Now at the National Bureau of Standards, Washington, D. C.

G10. On the Supercooling of Water. B. LUYET, *St. Louis University.**—Investigations on the possibility of solidifying water in the vitreous state† led to the following observations on some of the conditions in which water can be kept liquid at subzero temperatures. Droplets of water were projected with an atomizer onto a piece of glass 0.15 mm thick, and the latter, held by forceps mounted on a rotating arm, was swung into a cooling bath of petroleum ether and, after a minute, it was swung back into the focal plane of a polarizing microscope, between crossed nicols. The diameter of the drops on the glass varied from 0.1 to 1.5 mm. Despite the jarring, supercooling below −20°C was quite common, and several cases of supercooling below −30° were recorded; the smaller droplets were more frequently supercooled at the lower temperatures than the larger ones. But numerous apparent inconsistencies in the effect of the factors studied—temperature, size of the drops, cooling velocity, jarring, specimen of water used, even average time for the assumed chance formation of the nuclei—indicate that some fundamental factors causing the spontaneous crystallization of supercooled liquids are still unknown.

* With the assistance of G. Gardner.
† Work supported by Research Corporation.

G11. On Polarization in Electrolyte Solutions.* JOHN A. RIDER AND GEORGE JAFFÉ, *Louisiana State University.*—At the last Washington meeting one of the authors reported on a theory of polarization which, originally designed for crystals, can be made applicable to electrolytes by a generalization of the boundary conditions. Measurements to test the theory were performed in an ac bridge arrangement with a modified Jones bridge. The cell used was designed to bring out the characteristics of polarization, and was very different from the usually employed forms. It was in the shape of a plate condenser with guard ring, having relatively large surface and small (though variable) plate distance. The main difficulty which had to be overcome consisted in the enormous size of the capacitances which had to be balanced (up to 150 microfarads). The final measurements are in quantitative agreement with the theory as to the dependence of conductance and capacitance on concentration of the solutions, plate distance, and frequency. However, in order to explain the large capacitances, it is necessary to assume the presence of a group of ions (hydrated ions?) which have about 100 times smaller mobilities than ordinary electrolytic ions.

* Work supported by the ONR.

G12. Diamagnetic Properties of Adsorbed Gases. W. O. MILLIGAN AND HARRY B. WHITEHURST,* *Rice Institute.*—Adsorption isotherms have been obtained at 25°C on a silica gel, using water, n-propyl alcohol, acetic acid, salicylaldyde, and n-heptane as the adsorbents. At each point on the isotherms, the magnetic susceptibility of the adsorption complex was measured, using the Faraday method. At high pressures, near saturation, the observed dimagnetic susceptibilities correspond to the susceptibility of the bulk liquid. At low pressures corresponding to less than a monolayer, the susceptibility differed for the bulk liquid except for n-heptane. An increase in the diamagnetic susceptibility was observed for water and n-propyl alcohol, and a decrease for acetic acid and salicylaldehyde.

* Now at Owens-Corning Fiberglas Corporation, Newark, Ohio.

G13. Structural Constants of ClO_2. J. B. COON, *A & M College of Texas.*—Recent,[1] improved electron diffraction data for ClO_2, ($S'' = 1.491 \pm 0.014$A, $2\theta'' = 116.5° \pm 2.5°$), when compared with spectral data gives for the first time a check on the ground electronic state of ClO_2. Published work[2] shows that the rotational structure of the violet absorption spectrum of ClO_2 yields the following data: First difference between the $\Delta_1 F$'s interpreted as $2\bar{B}'' = 0.612 \pm 0.003$ cm^{-1}. Second difference between sub-bands interpreted as $2(\Delta A - \Delta\bar{B}) = -1.188$ cm^{-1}. Second difference in J structure interpreted as $2\Delta\bar{B} = -0.0615$ cm^{-1}. The three constants $2\bar{B}''$, S'', $2\theta''$ are dependent, and their experimental values given above are consistent within experimental error giving agreement between spectral data and electron diffraction data. In view of the electron diffraction results, the best values for S'' and $2\theta''$ exactly consistent with the above value of $2\bar{B}''$ are ($S'' = 1.484$A and $2\theta'' = 115.3°$). A preliminary result from some unpublished work by E. Ortiz and the author on the vibrational frequencies and their isotope shifts is $2\theta'' = 114.4°$. Starting with the above exactly consistent model and using the constants $2(\Delta A - \Delta\bar{B})$ and $2\Delta\bar{B}$, which determine the change in the moments of inertia, the bond distance and the angle of the excited electronic state may be determined: ($S' = 1.648$A and $2\theta' = 104°$). The sum of Pauling's single bond covalent radii for Cl and O gives $S' = 1.65$A.

[1] J. D. Dunitz and K. H. Hedberg, J. Am. Chem. Soc. 72, 3108 (1950).
[2] Jesse B. Coon, J. Chem. Phys. 14, 665 (1946).

G14. Reduction of Temperature Coefficient of Magnetic Moment for a Bar Magnet. R. W. LONG AND I. A. ROBERTSON, *Houston* (introduced by C. W. Heaps).—An arrangement of a magnetic shunt to sheath a cylindrical magnet has resulted in greatly improved magnetic stability. A bar magnet of 925 cgs

units magnetic moment, $\frac{3}{16}$ inch diameter and 2½ inches long was stabilized normally. Variations of its magnetic moment with temperature over a range of 10°C to 35°C were measured. The same magnet then was temperature compensated. Comparisons of data over the identical temperature ranges showed at least 25 times smaller variations. This can be further improved. Such magnets are of great interest in magnetic observatory work.

SATURDAY AFTERNOON AT 2:00

Physics Laboratory 210

(C. D. ANDERSON presiding)

Nuclear Physics; Cosmic Rays; Theoretical Physics

H1. Production and Detection of Circularly Polarized Gamma-Rays. OTTO HALPERN, *University of Southern California.*—It has been shown before[1] that capture of a polarized neutron by a nucleus followed by emission of a single quantum may lead to polarized products. The gamma-ray emitted in the direction of the neutron spin will sometimes be circularly polarized. Among several possible analyzers a special Compton effect[2] appears to be useful and simple. The cross section for backward scattering of moderately hard quanta depends strongly on the polarization of the scattering electron; it almost vanishes for one spin state and obtains therefore almost twice the value of the cross section for unpolarized electrons for the second spin state. Even if the scatterer is unpolarized the electron scattered forward is almost totally polarized which can be ascertained by a single Coulomb scattering experiment. A scatterer with polarized electrons is formed, e.g., by magnetized iron which contains about 24 unpolarized and 2 polarized electrons. The differential scattering cross section for the Compton process envisaged will therefore vary depending on the state of magnetization between 24 and 28 times the value obtaining for a single unpolarized electron. Other arrangements will be discussed.

[1] O. Halpern, Phys. Rev. **82**, 753 (1951).
[2] O. Halpern, Nature, 168 (1951).

H2. A Quadrature Method for Computing Neutron Distributions in Two Dimensions.* E. LEIGH SECREST,** *M.I.T.*—An iterative method has been developed, which, when combined with a quadrature approximation, leads to an approximate solution of the transport equation governing the scattering and absorption of multiply scattered neutrons. An integral relation for the distribution function was set up in a form suitable for iterative solution. To facilitate performance of the iterations, the assumption was made that the neutron distribution at a given point in space can be represented by flow along a finite number of streamlines (the quadrature approximation). The method was used to determine the effect of introducing a void in the form of a slit into a semi-infinite scattering medium (either capturing, or noncapturing, infinite or finite). Satisfactory results were indicated in boundary regions after a few iterations providing several quadrature directions were used for calculation of the iterative integrals. In regions distant to the slit a *small* number of *directions* combined with a *large* number of iterations was found satisfactory. Although the investigation was made primarily for the one-velocity transport equation, a procedure is indicated whereby energy dependence of the distribution can be included to some extent.

* Part of a thesis submitted to the Department of Physics of the Massachusetts Institute of Technology, in partial fulfillment of the requirements for the degree of Ph.D., supported by AEC Predoctoral Fellowship.
** Now Assistant Professor of Physics at North Texas State College, Denton, Texas.

H3. On the Diffusion of Thermal Neutrons. GEORGE JAFFÉ, *Louisiana State University.*—Considerable work has been performed on the theory of neutron diffusion within the last decade. However, as far as the author is aware, all theories start from a *linear* integral equation (the so-called "transport equation"), which neglects the motion of the moderator molecules. This can be included by starting from the original Boltzmann equation which is of the *second order* in the unknowns. The author has shown[1] how the Boltzmann equation can be transformed so as to represent the changes in a progressing beam. In this form it can be integrated for the case of thermal neutrons. It is necessary only to assume that the distribution of the moderator atoms is maxwellian, and that of the neutrons "almost maxwellian," i.e., given by the product of a maxwellian factor into a series progressing with general harmonics. If that is done, the problem is reduced to a set of differential equations which the author has established and solved in a very general way in his theory of the anisotropic radiation field as early as 1922. Thereby the results of this theory become immediately applicable to the diffusion of thermal neutrons.

[1] G. Jaffé, Ann. Physik **6**, 195 (1930).

H4. The Magnetic Moments of Nuclei. H. A. WILSON, *Rice Institute.*—On Dirac's theory an electron, with spin $s=\frac{1}{2}$, has a magnetic moment $2(s(s+1))^{\frac{1}{2}}he/4\pi m_p c$. We may therefore suppose that a nucleus with charge Ze and mass Am will have a magnetic moment $2(s(s+1))^{\frac{1}{2}}hZe/4\pi Amc$, where s is integral or half-odd integral. Dividing this by $he/4\pi m_p c$, where m_p is the mass of a proton gives $2(s(s+1))^{\frac{1}{2}}Zm_p/Am$. If the nucleus is rotating with spin I it will also have a magnetic moment $(I(I+1))^{\frac{1}{2}}Zm_p/Am$. The resultant magnetic moment is then $(j(j+1))^{\frac{1}{2}}gZm_p/Am$, where g is Lande's factor and j is the nuclear spin.

H5. On the Anomalous Magnetic Moments of Nucleons. FERNANDO E. PRIETO C.,* *Universidad de México.*—Using the neutral, charged, and symmetrical pseudoscalar theories of meson, and a combination of Dyson's, Feynman's, and Schwinger's computation methods, the electromagnetic and mesic corrections to the anomalous magnetic moments of nucleons have been calculated. It was found that only the symmetrical theory gives corrections to both the proton and the neutron moments. Adjusting the coupling constant to obtain the experimental value of the neutron moment, a value is obtained for the proton moment which is about 60 times smaller than the experimental one. The introduction of the electromagnetic correction does not improve these results because it is too small compared with the mesic correction.

* Instituto de Física de la Universidad Nacional de México and Instituto Nacional de la Investigación Científica.

H6. The Energy Spectrum of Primary Cosmic Radiation as Determined from Neutron Intensities.* M. S. VALLARTA, *Universidad de México.*—Using the neutron intensity measurements of J. A. Simpson and assuming that there is proportionality between number of neutrons measured and number of primary protons, the energy spectrum of the primary proton component of cosmic radiation can be determined by standard methods. If the spectrum is written in the form $n=K/E^{\gamma}$ (n = number of primary protons and E = energy), the analysis shows that γ increases from the value 1.175 in the low energy range (1.3 to 4.3 Bev) to 1.815 in the medium energy range (4.3 to 14 Bev). This is in agreement with results derived from measurements on charged secondary particles at balloon and rocket altitudes.

* Research done under the auspices of Instituto Nacional de la Investigación Científica, México, D. F.

H7. Time Dependent Description of Resonance Reactions.* MARCOS MOSHINSKY, *Universidad de México.*—It is known that cross sections for resonance scattering and reaction, can be derived from appropriate boundary conditions[1] connecting the stationary wave functions and their normal derivatives at the nuclear surface. An extension of these boundary conditions to time dependent states has been achieved with the help of a description of resonance reactions in Fock space.[2] We make use of these boundary conditions to obtain a time dependent description for the process of single level elastic scattering. With the help of an appropriate generalization of the concept of hankel transform, an explicit form is obtained for the time dependent wave function representing the scattering process, and the only parameters present in the wave function are the poles of the scattering matrix. A discussion of the asymptotic behavior of this wave function when $t\rightarrow\infty$, shows that a causal description of the process of scattering can only be obtained if the poles of the scattering matrix are in the lower half-plane of the wave number k, or on the imaginary axis.[3] Extensions of this time dependent description to the case of many level scattering, and to nuclear resonance reactions, will be discussed.

* This work is supported by the Instituto Nacional de la Investigación Científica.
[1] E. P. Wigner, Phys. Rev. **70**, 606 (1946).
[2] M. Moshinsky, Phys. Rev. **81**, 347 (1951).
[3] W. Schützer and J. Tiomno, Phys. Rev. **83**, 249 (1951).

H8. Fourth-Order Effects in Vacuum Polarization.* JUAN DE OYARZABAL, *Universidad Nacional de México.*—The covariant S matrix formalism of Dyson[1] has been applied to the calculation of the fourth order effects in the polarization of vacuum by an electromagnetic field. Explicit form for the function $A^{e}(x)$, the external electromagnetic field modified by the interaction with the pair field, is given to order α^2.

* This work was performed under the auspices of the Instituto Nacional de la Investigación Científica of Mexico City.
[1] F. J. Dyson, Phys. Rev. **75**, 486, 1736 (1949).

H9. The Classical Quantum Electrodynamics of Interacting Fields. M. DRESDEN AND H. DEAN BROWN, *University of Kansas.*—The customary technique employed in problems in field theory is a perturbation calculus, a development in powers of the coupling parameter. In many instances this development is not appropriate and other development schemes have been constructed as in the strong-coupling theories. However, the description of the intermediate coupling case, as well as the variation of the physical characteristics with the coupling parameter, are not too transparent in these schemes. To investigate these points, an elementary example has been studied in some detail. The system chosen consists of two interacting neutral scalar fields, both fields possessing quanta of finite rest mass. The lagrangian density of the system has the form

$$L=-\frac{\hbar c}{2k_1}\left[\left(\frac{\partial\psi_1}{\partial x_\mu}\right)^2+k_1^2\psi_1^2\right]-\frac{\hbar c}{2k_2}\left[\left(\frac{\partial\psi_2}{\partial x_\mu}\right)^2+k_2^2\psi_2^2\right]-\tfrac{1}{2}g(\psi_1+\psi_2)^2.$$

The coupling term is slightly different from the more usual $g\psi_1\psi_2$ this form is essential for the discussion if arbitrary large values of g are allowed. This problem can be solved exactly for all g, with the help of a canonical transformation, which separates the hamiltonian of the system into the hamiltonian of four uncoupled fields.

H10. The Positional Correlations in Interacting Fields. H. DEAN BROWN AND M. DRESDEN, *University of Kansas.*—The use of the uncoupling canonical transformation allows the explicit calculation of energies and wave functionals in the problem of two interacting fields. Since the calculation methods utilized are noncovariant one encounters the usual divergencies. The dependence of the energy—even in the ground state of the system—on the coupling parameter, is rather complicated. It is for instance not true—except in the limit of very weak coupling—that this energy splits up additively in terms which represent the energy of the separate fields and the interaction energy respectively. In many treatments one of the fields is considered as static, then the application of a perturbation procedure enables one to obtain an expression for the potential energy between the sources of the static field. In the present discussion neither field was treated in the static approximation, it has not appeared possible to separate the energy in field energy and interaction energy, or in static and nonstatic parts. It would seem quite difficult to attribute an unambiguous significance to potential energy in this situation. It can be shown, that the quantity $\langle\psi_1(x_1)\psi_2(x_2)\rangle_{Av}$ the positional correlation function, exhibits some of the characteristics of a classical interaction energy.

H11. Scattering of Strongly Coupled Pseudovector Mesons. MELVIN EISNER, *A. & M. College of Texas.*—The differential scattering cross section for the scattering of strongly coupled pseudovector mesons by nucleons has been calculated. Successive canonical transformations are used to reduce the hamiltonian to a simple form, resembling the pseudoscalar hamiltonian. The differential cross section for mesons of momentum k_0 is

$$\sigma(\theta)=a^2/4\cdot(k_0/\omega_0)^4\cdot[(g^2-\mu^2f^2)/(2\mu^2f^2+g^2)]^2\cdot(1-\cos^2\theta),$$

where g and f are coupling constants and a is the "half-width" of the nucleon density distribution function. The nucleon recoil has been neglected and no distinction has been made between elastic and inelastic scattering. The cross section is of the order of 10^{-28} cm^2 for a choice of 10^{-14} cm for a, and selection of f and g compatible with the condition for strong coupling.

H12. Nuclear Masses as Integral Multiples of a Natural Unit of Mass. ENOS E. WITMER, *University of Pennsylvania.*—Some time ago the writer proposed the hypothesis that the masses of those nuclei not subject to beta-decay are integral multiples of a natural unit of mass for nuclei and elementary particles. This unit was designated the *prout* and it was taken to be one-eleventh of the rest mass of the negative electron. Recently important new tables[1, 2] of nuclear masses and reaction energies have appeared. Taking the mass of the proton to be 20 197 prouts, the nucleus of O^{16} is found to have

320 629 prouts. Hence 1 prout = 0.0000498 882260 $m\mu$ = 46.4523 kev. With this value of the prout the data of references 1 and 2 are in good agreement with our hypothesis. Our computed values of the isotopic masses of H^1, H^2, and C^{12} are 1.008 1413, 2.014 7360, and 12.003 8045 $m\mu$ respectively. Also most nuclei up to O^{16} that are subject to beta decay conform to the integral rule stated here, but not the neutron. Five of the nuclear masses in prouts up to O^{16} are divisible by 11.

[1] Li, Whaling, Fowler, and Lauritsen, Phys. Rev. **83**, 512 (1951).
[2] Heinz Ewald, Z. Naturforsch. **6a**, 293 (1951).

Saturday Afternoon at 4:30

Cohen House

Tea offered by Rice Institute to members of the Society and to guests

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